Estimating nucleus-nucleus fusion cross sections

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Together with Polish physicists J. Wilczynski and K. Siwek-Wilczynska we are developing a theory of the cross-sections for the fusion of target and projectile nuclei designed to produce heavy and superheavy elements. For lighter systems the cross section can be considered as the usual product of two energy-dependent factors: the cross section for the two nuclei to stick (i.e., for the target to *capture* the projectile) and the probability for the resulting compound nucleus (which automatically follows capture) to *survive* the risk of fission during the de-excitation process. However, beyond a certain critical size of the system, a third factor enters, the entrance channel hindrance identified in the eighties under the name of the "extra push". This hindrance is due to the fact that for the heavier target-projectile combinations the nuclei, after getting stuck, correspond to a system on the wrong side of the saddle-point barrier that needs to be overcome in order to reach the compound nucleus configuration. In order to estimate quantitatively the associated hindrance, we make use of the everyday observation that, after contact of two fluid drops, there takes place a very rapid growth of the neck at a virtually fixed overall length of the system. This neck snap is driven by the great reduction of the surface energy achieved at the price of only a minor, local mass flow. The configuration resulting from minimizing the energy with respect to the neck size at fixed overall length defines an "optimum valley" in configuration space. After the snap the system is thus in this valley at a location corresponding approximately to the sum of the diameters of target and projectile. We have found it possible to develop algebraic formulae for estimating the potential energy V in the optimum valley for a range of systems of interest, and we are exploring the hypothesis that the hindrance factor can be approximated by a Boltzmann term, exp(-B/T), where B is the difference between the saddle-point energy and V, and T is the nuclear temperature associated with the excitation energy, given by the difference between the center-of-mass energy and V [1]. Preliminary estimates using this "CBS model" (*Capture*Boltzmann*Survival*) appear to be in qualitative agreement with a number of measured cross sections for making elements with atomic numbers Z=102 to 112. This work is supported in part by the U.S. – Poland Maria Sklodowska-Curie Fund No. PAA/NSF-96-253.

[1] W. Myers and W. J. Swiatecki, *At the extremes of nuclear charge and spin*, Acta Physica Polonica **B 32**, 1033 (2001).